

EXHIBIT A

**REDACTED VERSION OF
DOCUMENT SOUGHT TO BE
SEALED**

IN THE UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
SAN JOSE DIVISION

SPACE DATA CORPORATION,)
)
)
Plaintiffs,)
)
)
v.) Case No. 5:16-cv-03260-BLF
)
)
ALPHABET INC., GOOGLE LLC, AND)
LOON LLC,)
)
)
Defendants.)
)
)
)

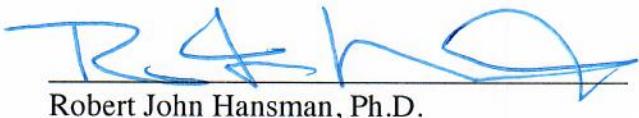
REBUTTAL EXPERT REPORT OF ROBERT JOHN HANSMAN, Ph.D.

REGARDING NON-INFRINGEMENT OF
U.S. PATENT NOS. 9,643,706 AND 9,678,193

AND

SPACE DATA'S ASSERTED TRADE SECRETS
AND CONFIDENTIAL INFORMATION

CONTAINS HIGHLY CONFIDENTIAL—ATTORNEYS' EYES ONLY INFORMATION



Robert John Hansman, Ph.D.

November 16, 2018

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testimony provided in this case. I also reserve the right to respond to any additional or revised opinions or theories of infringement of which I am not currently aware.

13. At this time, I have not created any exhibits to be used as a summary of, or as support for, my opinions apart from the materials below and attached to this report. I reserve the right to create any additional summaries, tutorials, demonstratives, charts, drawings, tables, and/or animations that may be appropriate to supplement or demonstrate my opinions, if I am asked to testify at trial.

III. QUALIFICATIONS AND EXPERIENCE

14. I received a Bachelor's degree in 1976 from Cornell University, a Master's degree in Physics in 1980 and an interdisciplinary Ph.D. in Physics, Aeronautical and Astronautical Engineering, Electrical Engineering, and Meteorology in 1982 from MIT.

15. Since 1982, I have taught and conducted research in the Department of Aeronautics and Astronautics at MIT, initially as a Lecturer from 1982 through 1983, then as an Assistant Professor from 1983 through 1984, the Boeing Assistant Professor of Aeronautics and Astronautics from 1984 through 1985, the Esther and Harold E. Edgerton Assistant Professor from 1985 through 1987, an Associate Professor from 1987 through 1995, and a Professor from 1995 through 2006. Most recently, in 2006, I was appointed the T. Wilson Professor of Aeronautics and Astronautics.

16. I teach undergraduate and graduate courses in aircraft design and systems engineering, flight testing, spacecraft and aircraft instrumentation, flight guidance, airline management, and human supervisory control. I have conducted research in a broad range of air transportation topics, including using information technology to improve safety and efficiency.

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17. Over the course of my career, I have been a member of numerous organizations related to aeronautics, including the National Academy of Engineering (NAE), National Research Council Aeronautics & Space Engineering Board, American Institute of Aeronautics & Astronautics (Fellow), Royal Aeronautical Society (Fellow), NASA Aeronautics Advisory Council, Soaring Society of America (Director), Soaring Safety Foundation (Director), Atmospheric Environment Technical Committee, American Meteorological Society, Society of Automotive Engineers, Human Factors Society, Aeronautical Flight Measurements and Techniques Working Group, and Editorial Board of *Air Traffic Control Quarterly* and *Journal of Aircraft*.

18. Since 1982, I have served as a consultant and advisor on various aerospace-related topics. I am the chair of the U.S. Federal Aviation Administration Research Engineering & Development Advisory Committee (REDAC) and the co-director of the FAA Center of Excellence in Aviation Sustainability (ASCENT).

19. I received the AIAA Award for Best Paper in Thermophysics, the Presidential Young Investigator Award, the AIAA Losey Atmospheric Sciences Award, the FAA Excellence in Aviation Award, the Bose Award for Excellence in Teaching, and the Kriske Career Award from the Air Traffic Control Association.

20. I have over 6,000 hours of pilot in-command time in airplanes, helicopters and sailplanes, including meteorological, production and engineering flight test experience.

21. I am the named inventor on U.S. Patent Nos. 4,365,131; 4,628,726; 4,729,245; 5,039,439; 5,313,202; 6,389,333; and 7,428,449, which deal with methods of ice prevention and de-icing, flight information and control systems, low gravity fluid measurement systems, and systems and methods of workload determination.

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22. I have authored more than 300 technical publications, including those listed in my *curriculum vitae*.

23. As part of my activities at MIT, I have led a number of aircraft and UAV design and development efforts, which has included the design and development of lighter-than-air platforms. These include simple lighter than air designs as part of undergraduate classes and several hybrid lift vehicle designs developed in collaboration with the Lockheed Martin Skunk Works. I have designed and developed and used flight termination systems, most recently for the Jungle Hawk Owl long endurance UAV.

24. A true and correct copy of my *curriculum vitae* is attached as **Exhibit 2** and incorporated herein by reference.

IV. LEGAL STANDARDS

25. I am not an attorney or a legal expert, and I offer no opinions on the law. I have relied on instructions from counsel as to the applicable legal standards to use in arriving at my opinions in this Report.

A. Patent Infringement

26. I have been informed and understand that determining whether an asserted patent claim is directly infringed involves a two-step inquiry. First, the claim must be construed to determine its proper scope and meaning to one of ordinary skill in the art. Second, to find infringement by an accused product or method, the patent owner must show the presence of every limitation of the claim in the accused product or method either literally or under the doctrine of equivalents. I understand that there can be no infringement unless every limitation of the claim is present in the accused product or method either literally or equivalently.

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The image consists of a vertical stack of approximately 20 horizontal black bars. The bars vary in length, with some being relatively short and others extending almost to the top of the frame. Small black squares are placed at the ends of certain bars: a pair at the very top left, a single square at the end of the second bar from the top, a single square at the start of the fourth bar from the top, a pair at the end of the eighth bar, a single square at the start of the ninth bar, a single square at the end of the 13th bar, a pair at the start of the 14th bar, and a single square at the end of the 18th bar.

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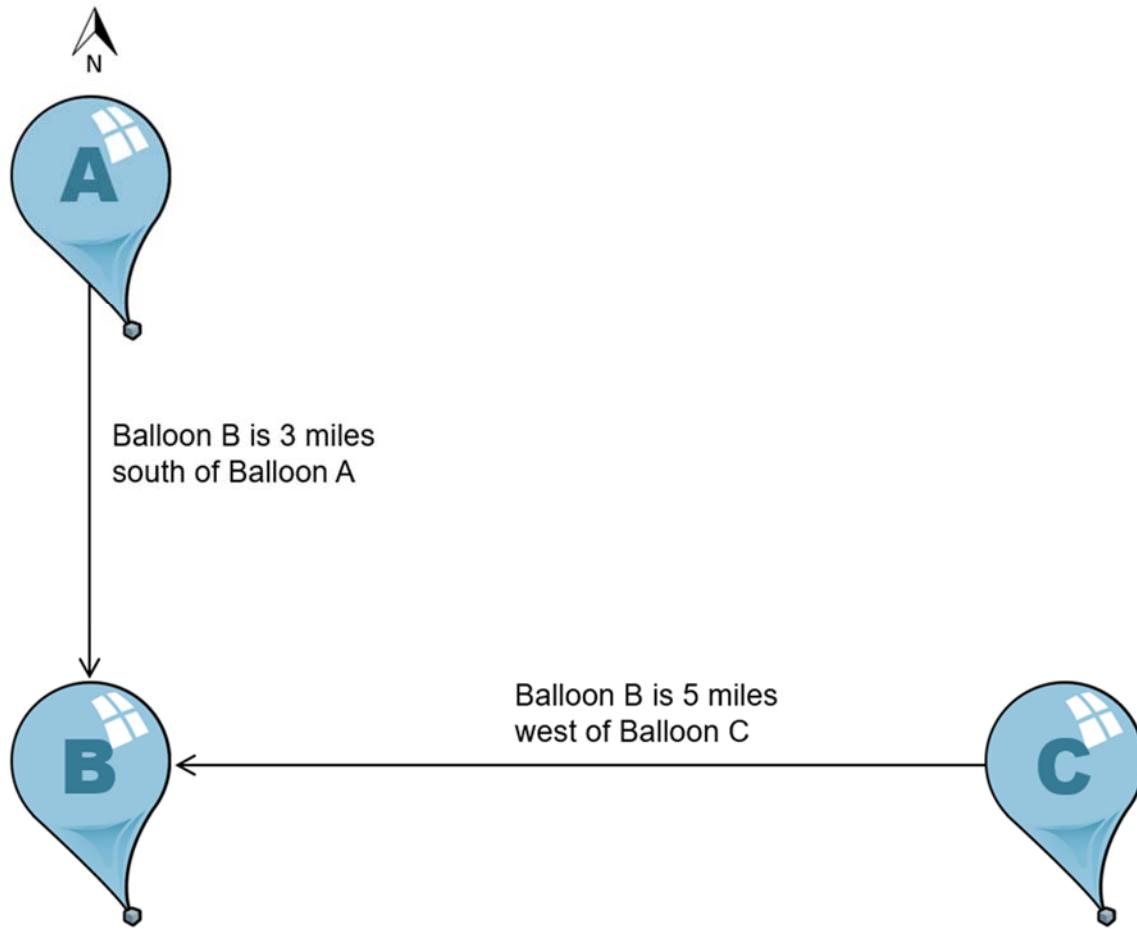
138. I disagree with Space Data’s and Dr. Pullen’s contention that the Loon system infringes claim 1 of the ’193 patent. Based on my analysis, it is my opinion that the Loon system does not infringe claim 1 of the ’193 patent.

a. **The Loon system does not perform the method step of “determining locations of one or more neighbor balloons relative to the determined location of the target balloon.”**

139. Claim 1 requires, among other limitations, the step of “determining locations of one or more neighbor balloons relative to the determined location of the target balloon.” In other words, the system must determine the *relative* location of balloons within the system.

140. Relative location has a standard meaning to one of skill in the art. A relative location is a location that is measured in relation to some other object or reference point—*i.e.*, it is a *vector* measured as the distance and direction from one object to another (*e.g.*, the relative location of Balloon B from Balloon A).

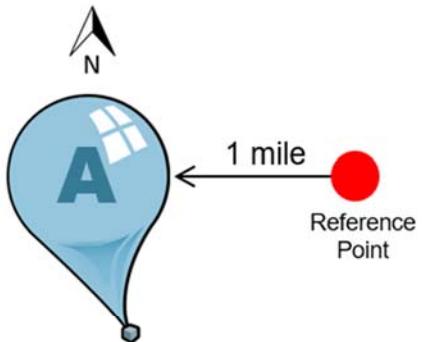
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141. Because a relative location is, by definition, determined in relation to another object or reference point, the same object will have different relative locations depending on what is used as the reference. In the balloon network illustrated above, for example, Balloon B has a relative location 3 miles south of Balloon A, but Balloon B also has a relative location 5 miles west of Balloon C.

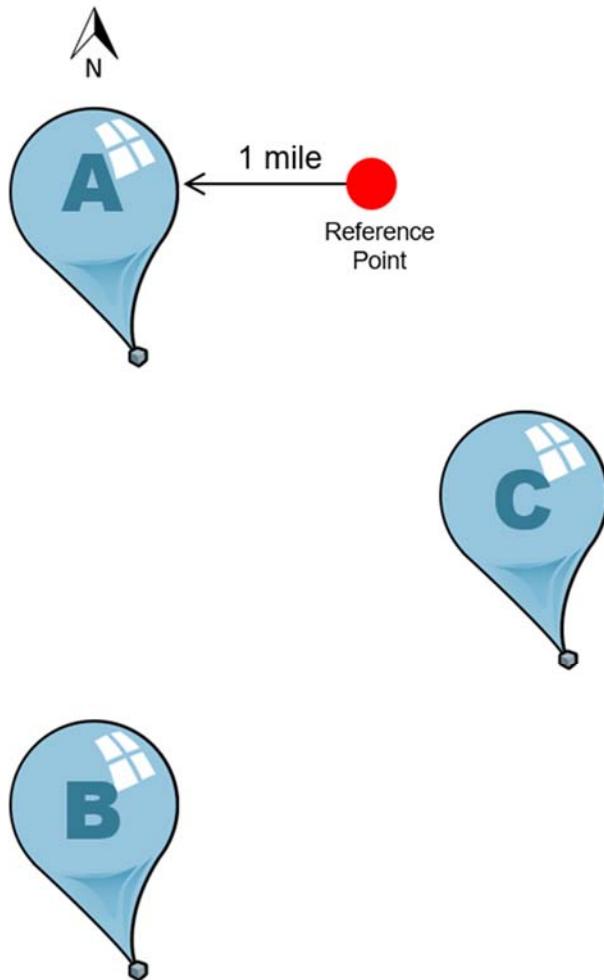
142. In contrast to a relative location, an absolute location is measured in relation to an absolute reference point (such as a fixed point on earth) or based on a fixed coordinate system (such as latitude, longitude, and altitude). When measuring the location of a balloon from an absolute reference point, the location of other balloons within the network is irrelevant.

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As an example, in the balloon network illustrated above, the location of Balloon A is 1 mile west of the absolute reference point on earth, shown as a red circle. Unless Balloon A moves, its location relative to that reference point will not change.

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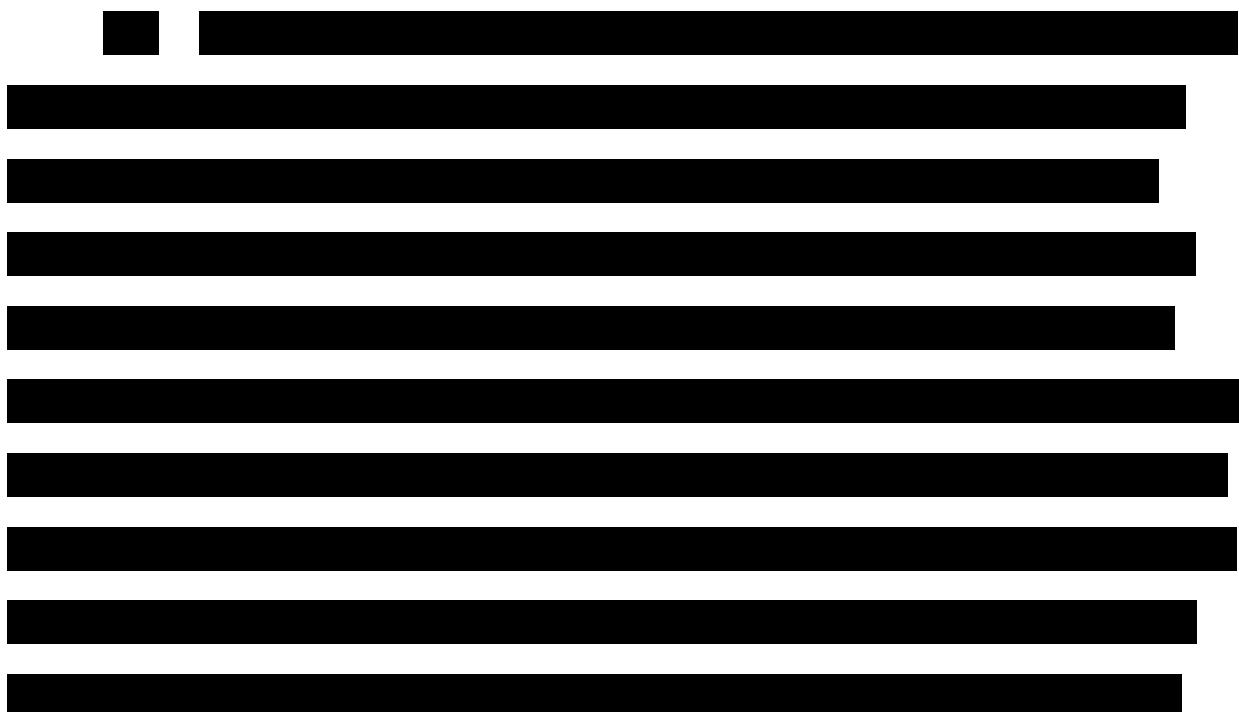
As illustrated above, if Balloon C moves, the location of Balloon A relative to the location of Balloon C would be different, but the absolute location of Balloon A would be unchanged.

143. Claim 1 requires the step of “determining locations of one or more neighbor balloons relative to the determined location of the target balloon.” Thus, to infringe, the system must (a) determine the location of the target balloon and then (b) must also determine the location of one or more of its neighbors *relative to* the determined location of that target balloon. And for that second step, the system must determine the vector (*i.e.*, distance and direction) that the neighbor balloon is from the target balloon.

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144. In other words, to infringe claim 1, it is not sufficient to determine the location of the neighbor balloon in relation to an absolute reference point (such as a point on earth) and to also determine the location of the target balloon in relation to the same absolute reference point. Rather, the claim language requires determining the location of the neighbor balloons “relative to” the location of the target balloon.

145. As noted above, the '193 patent describes a method for maintaining the desired spacing ***between*** balloons and therefore requires determining the location of a balloon ***relative to*** its neighbors. In contrast, the Loon stratospheric communications system does not, "determin[e] locations of one or more neighbor balloons relative to the determined location of the target balloon." '193 patent, claim 1. Specifically, the Loon system does not determine the location of any balloon in the network relative to the location of any other balloon in the network. In short, at no step in the control of Loon's network of balloons does the system determine the distance and direction of one balloon from any other balloon within the network.



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The image consists of a series of horizontal black bars of varying lengths, arranged vertically. The bars are solid black and have thin white borders. They are positioned against a white background. There is a significant gap at the bottom of the page where the bars are shorter, and a large, solid black rectangular area covers the bottom third of the page.

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The image consists of a series of horizontal black bars of varying lengths, arranged vertically. Some bars have small black squares at their left ends. The bars are set against a white background.

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322. I have reviewed all the photographs taken by Google's representatives during their February 15, 2008 tour of Space Data that have been produced in discovery in this action. Based on that review, it is my opinion that none of the photographs reveal non-public information concerning Space Data's Asserted Technical Trade Secrets, individually or collectively.

323. Many of the photographs are of the Google team's journey to and from Arizona. *See* GOOG-SD-00074305; GOOG-SD-0074323–2; GOOG-SD-0074327–29; GOOG-SD-0074331–43; GOOG-SD-00080966; GOOG-SD-00080981–83; GOOG-SD-00080985; GOOG-SD-00080998; GOOG-SD-00081003–06; GOOG-SD-00074283–98; GOOG-SD-00074310–12; GOOG-SD-00074315; GOOG-SD-00074317; GOOG-SD-00074320; GOOG-SD-00080967–75; GOOG-SD-00080984–90; GOOG-SD-00293623; and GOOG-SD-00293632–37. These photos clearly do not contain any confidential Space Data information.

324. Many other photographs are of the launching of Space Data balloons with payloads from the parking lot of Space Data's offices. *See* GOOG-SD-00074305; GOOG-SD-0074323–25; GOOG-SD-0074327–29; GOOG-SD-0074331–43; GOOG-SD-00080966; GOOG-SD-00080981–83; GOOG-SD-00080985; GOOG-SD-00080998; GOOG-SD-00081003–06; and GOOG-SD-00293624–30. I understand that Space Data does not consider its balloon launches, or anything discernable from observing a launch or the exterior of one of Space Data's payloads, to be confidential. *See* Knoblach Rule 30(b)(6) Dep. Tr. at 329:6–331:17. And, in any event, I have reviewed various news broadcasts from Space Data's offices showing Space Data's balloons being launched that, in my opinion, provide as much or more information about Space Data's balloons, the exterior of its payloads, and its balloon launch procedures as the Google

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balloon launch photos. *See, e.g.*, GOOG-SD-00292607; GOOG-SD-00296778; SD_825705; SD_825706; and SD_825708.

325. [REDACTED]

[REDACTED] I understand that Space Data is not asserting that this process is one of its trade secrets. *See* Trade Secret Disclosure at 1–12. And this process is also depicted in the public news broadcasts about Space Data. *See* SD_825705; SD_825706; and SD_825708.

326. [REDACTED]

[REDACTED]. I understand that Space Data is not asserting that Google has misappropriated any trade secrets related to its balloon manufacturing process or misused any confidential information related to that process. *See* Trade Secret Disclosure at 1–12.

327. [REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

328. [REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]

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[REDACTED]

[REDACTED].

329. I understand that Space Data has periodically permitted television news reporters and other journalists to record and broadcast stories from inside Space Data's NOCC. As noted above, I have reviewed some of these news broadcasts, and it is my opinion that the information concerning Space Data's NOCC visible in or discernable from [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

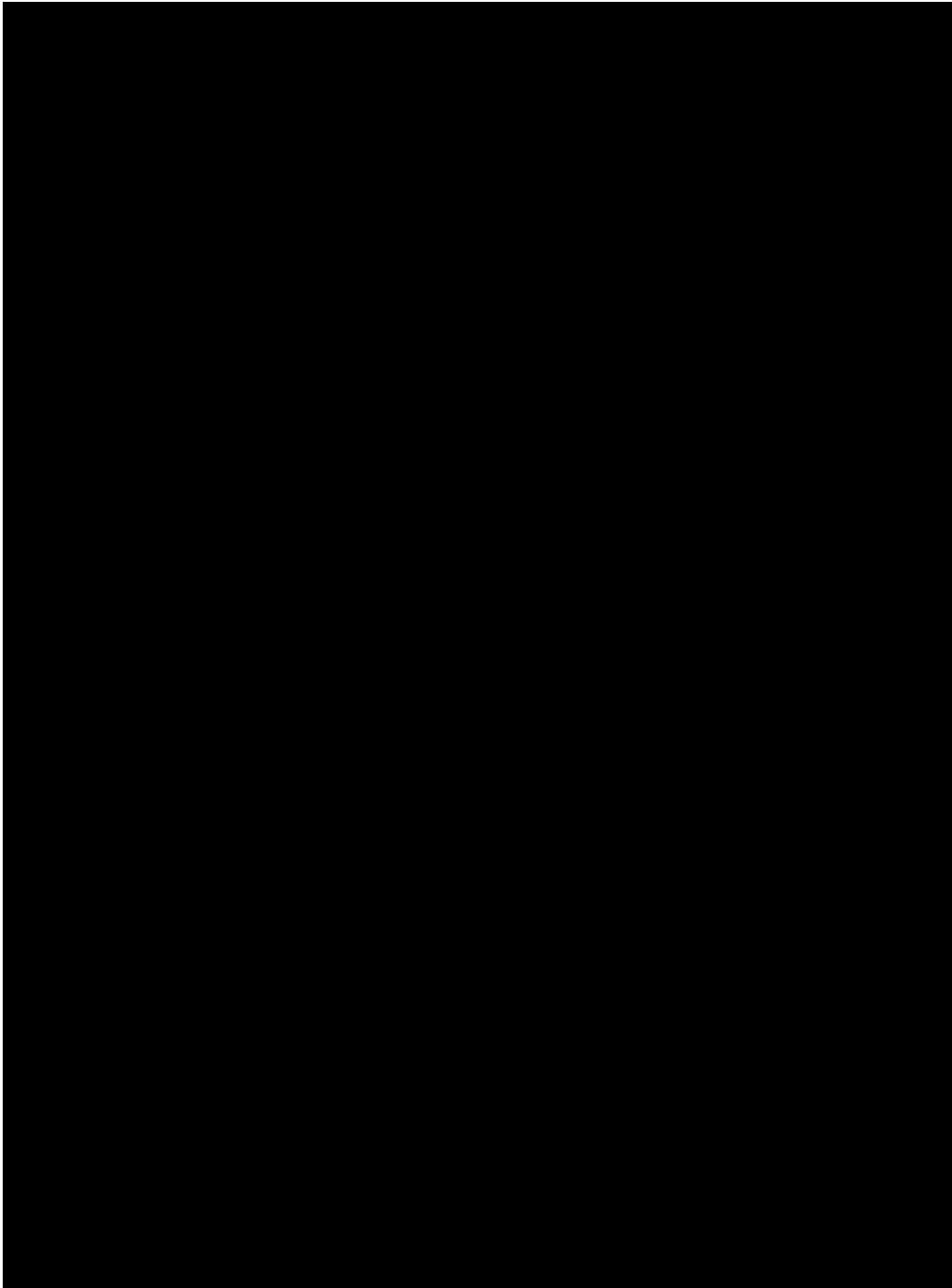
[REDACTED]

[REDACTED].

330. For example, reproduced below are representative examples of the photographs taken by Google in the NOCC:

[REDACTED]

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331. In comparison, reproduced below are screenshots of Space Data's NOCC from a WSJ.com online video news story about Space Data:

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GOOG-SD-00292607. According to the WSJ website, this video of Space Data's NOCC appears to have been taken around the same time that Google visited Space Data. *See* <https://www.wsj.com/video/bringing-wireless-to-hinterlands/DF067123-A7C8-4284-B50F-60A0B1EAC923.html> (showing a date of “Feb. 20” in the video description, which matches the Feb. 20, 2008 publication date of the accompanying WSJ printed news story on Space Data). I also understand from Mr. Knoblach’s testimony that Wall Street Journal reporter Amol Sharma

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toured Space Data's facilities in early February 2008, shortly before Google's visit. *See* Knoblauch Rule 30(b)(6) Dep. Tr. at 533:23–534:4.

332. Similarly, here are screenshots of Space Data's NOCC from a Phoenix, Arizona FOX affiliate television news broadcast from within Space Data's NOCC:



GOOG-SD-00296778. According to Space Data's website, this video of Space Data's NOCC was taken around March 2008. *See* <https://www.spacedata.net/news/in-the-news/>.

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Additionally, here is another screenshot from a different news broadcast from Space Data's NOCC by the same Phoenix, Arizona FOX television station:



GOOG-SD-00296776. According to Space Data's website, this video of Space Data's NOCC was taken around June 2010. See <https://www.spacedata.net/news/in-the-news/>.

333. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

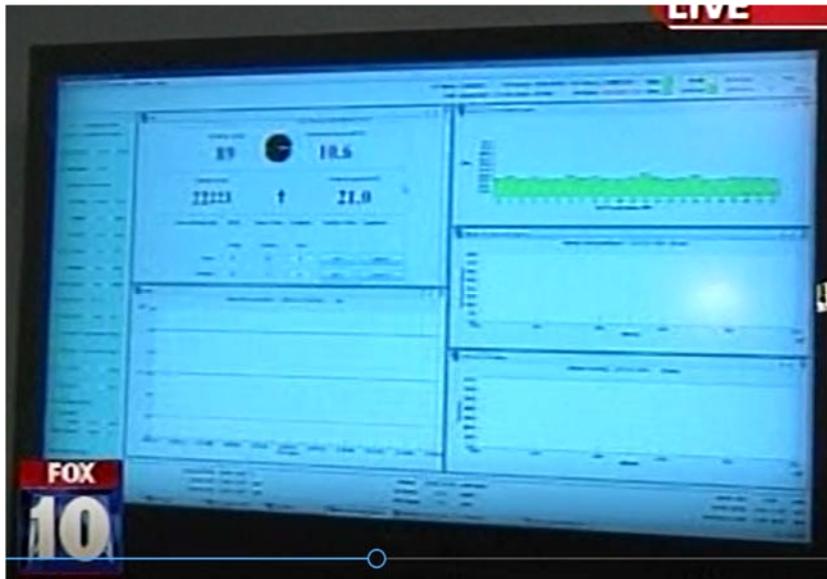
[REDACTED]

334. [REDACTED]

[REDACTED]

[REDACTED], the public news broadcasts that I have reviewed do depict such information. Reproduced below are two examples:

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GOOG-SD-00296776.



SD_825708.

335. [REDACTED]

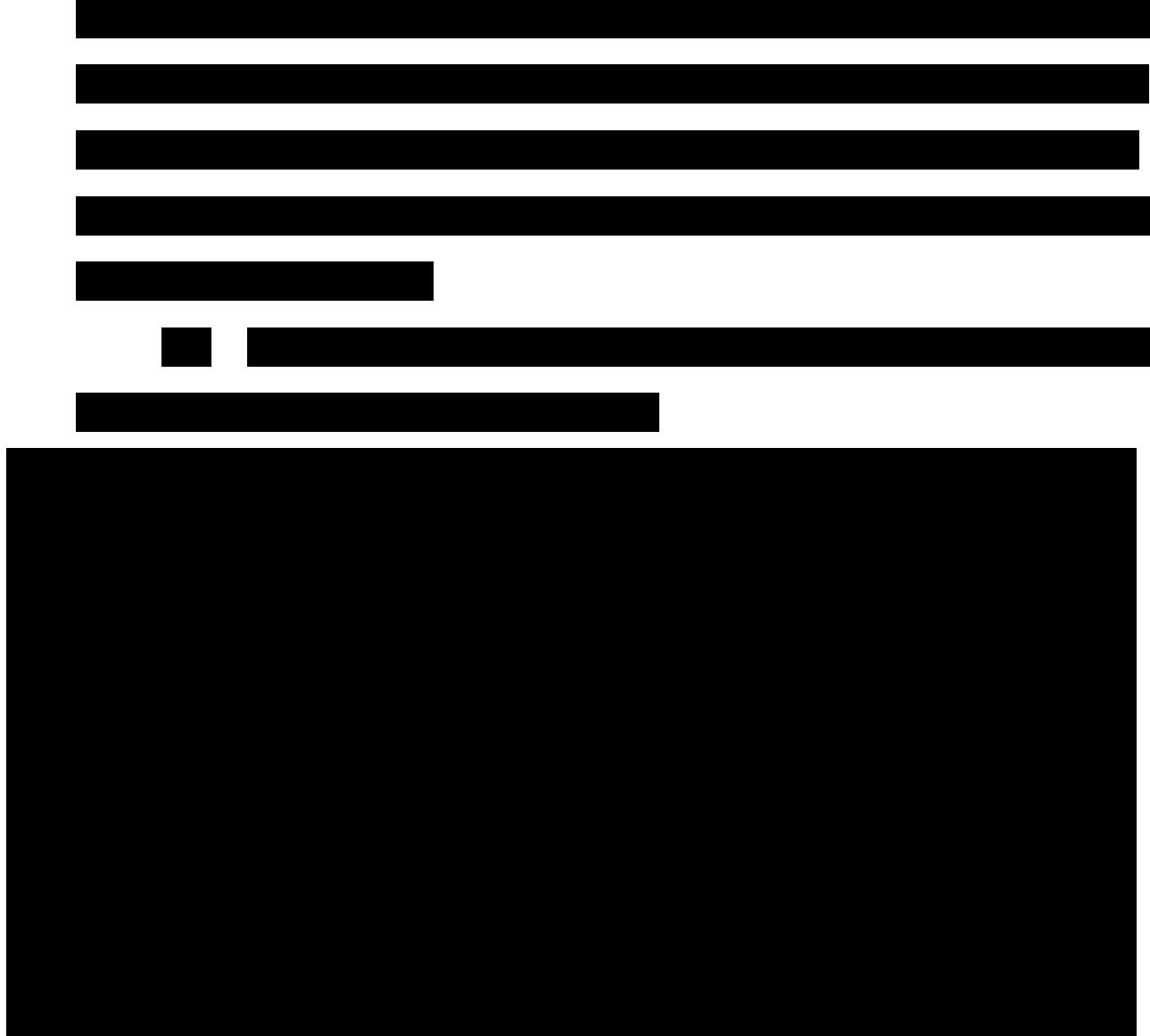
[REDACTED]

[REDACTED]

[REDACTED]

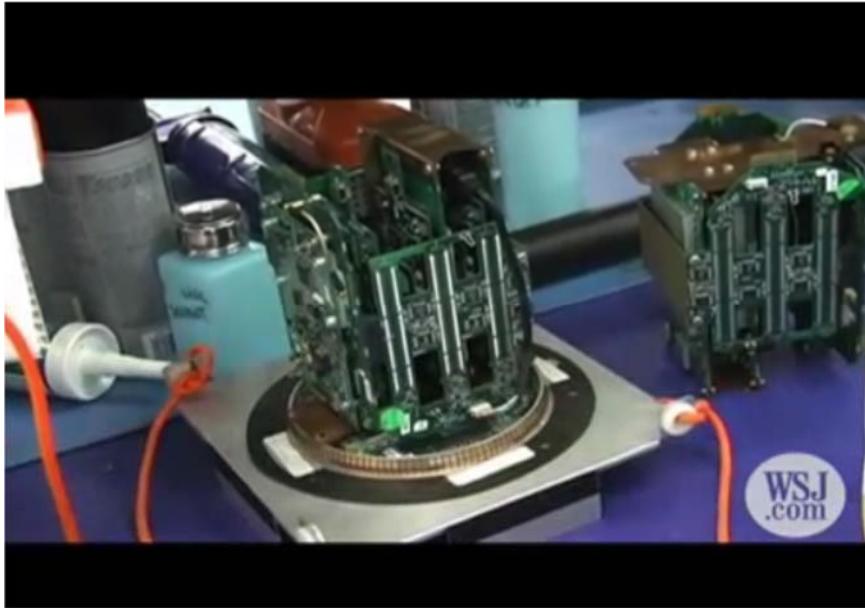
[REDACTED]

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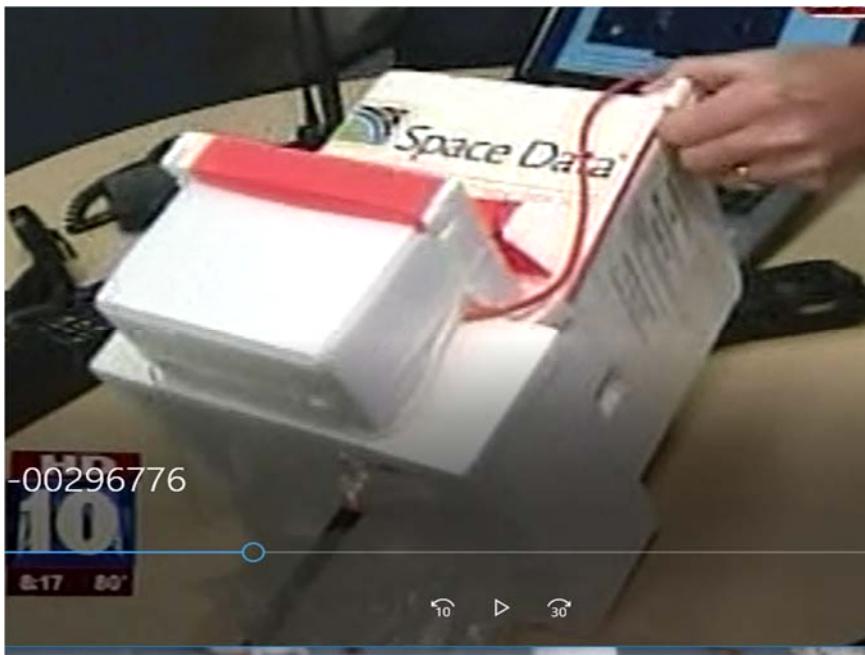
337. And here is a screenshot from the February 2008 WSJ.com video news story discussed above showing Space Data's payload:

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GOOG-SD-00292607.

338. And here is a screenshot from the March 2008 Fox news broadcast, showing the foam insulation exterior of Space Data's payload:



GOOG-SD-00296776.

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339. Similarly, here is an image from a Space Data presentation dated 2015 that I understand is publicly available on the internet:



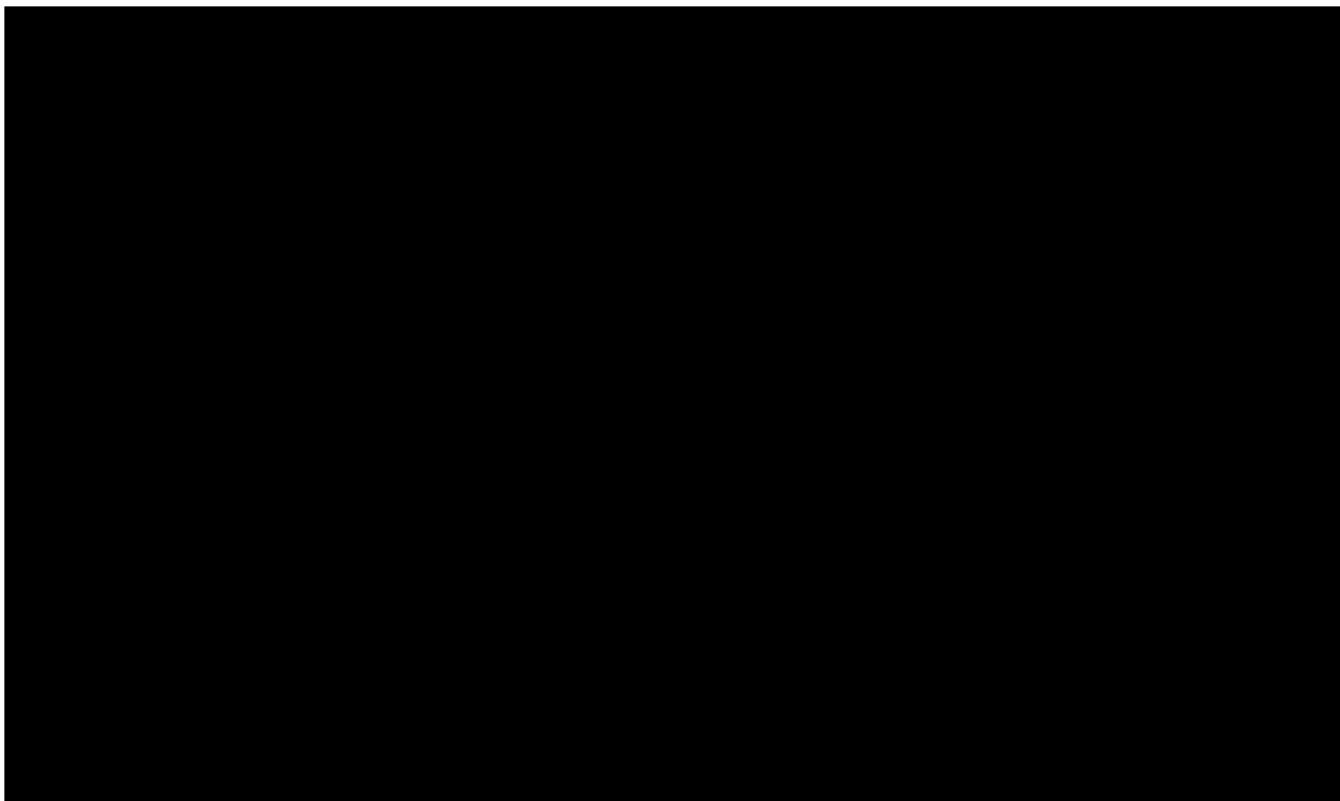
GOOG-SD-00301199–230 at -205 (available at <https://docplayer.net/11167153-Connecting-air-ground-operators-through-the-upper-aerial-layer.html> (last accessed November 13, 2018)).

340. In sum, in my opinion neither the Google photographs reproduced above nor any others that I have reviewed disclose any more about the subject matter of Space Data Asserted Technical Trade Secrets than the WSJ.com video and other news broadcasts from Space Data's facilities and other public disclosures by Space Data that I have reviewed.

[REDACTED]

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HIGHLY CONFIDENTIAL—ATTORNEYS' EYES ONLY



HIGHLY CONFIDENTIAL—ATTORNEYS' EYES ONLY

- [REDACTED]
- [REDACTED] [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED] [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED] [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED] [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED] [REDACTED]
- [REDACTED]
- [REDACTED]

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HIGHLY CONFIDENTIAL—ATTORNEYS' EYES ONLY

2. Dr. Meyer's statements concerning interactions between Google employees who visited Space Data and Loon.

359. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

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362.

A horizontal bar chart consisting of eight solid black horizontal bars of decreasing length from top to bottom. The bars are evenly spaced vertically.

C. Dr. Meyer's Statement Concerning the Value of Space Data's Asserted Technical Trade Secrets to Google

363.

A large black rectangular redaction box covers the central portion of the page. In the bottom right corner of this redacted area, there is a single small white square.

364. Dr. Meyer offers no basis for her conclusions regarding the supposed benefits to Google of Space Data's alleged trade secrets, individually or collectively, beyond Space Data's

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A horizontal bar chart illustrating the percentage of respondents who have heard of different topics. The y-axis lists the topics, and the x-axis represents the percentage from 0% to 100%. The bars are black.

Topic	Percentage
Healthcare	98%
Technology	95%
Finance	92%
Politics	90%
Entertainment	88%
Science	85%
Food	82%
Sports	78%
Business	75%
Art	72%
Lifestyle	68%
History	65%
Culture	62%
Environment	58%
Geography	55%
Mathematics	52%
Physics	48%
Chemistry	45%
Biology	42%
Medicine	38%
Engineering	35%
Astronomy	32%
Physics	30%
Chemistry	28%
Biology	25%
Medicine	22%
Engineering	20%
Astronomy	18%
Physics	15%
Chemistry	12%
Biology	10%
Medicine	8%
Engineering	5%
Astronomy	3%
Physics	2%
Chemistry	1%
Biology	0.5%
Medicine	0.2%
Engineering	0.1%
Astronomy	0.05%

370. For example, the specification of the '193 patent discloses: "To form the constellation of airborne communications platforms, paging transceivers are attached to lighter-than-air carriers, such as high altitude balloons similar to those used by the National Weather Service (NWS) yet modified to provide for regulated adjustable altitude control using methods such as venting and ballast dropping. . . Computer regulated altitude control and computerized

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tracking are utilized. The SNS platforms are regulated to maintain a desired altitude within a predetermined altitude range, as, for example, in the stratosphere over Earth, as they drift along with existing wind currents.” ’193 patent at 11:38–43; 11:54–58. The specification goes on to describe in detail how to implement such a stratospheric balloon communications system.

371. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED].

372. A 2003 article by Space Data’s Chief Technology Officer, Eric Frische, entitled “A Low-Cost, Free Drifting Ballooncraft Constellation Providing Telecommunications to Rural Areas,” includes a detailed discussion of Space Data’s system and technology. SD_191247–57. It discloses, among other information:

Wind patterns at 100,000 feet are dominated by large global circulation flows which are uniform and have generally predictable seasonal variations. Over 60 years of National Weather Service meteorological data is available to provide baseline data for simulations verifying that the winds are uniform enough to maintain an evenly spaced constellation. Once aloft, the future position of each SkySite Platform in the constellation can be projected. Based on this predictive knowledge, Space Data’s SkySite Control Center (SCC) can proactively launch individual SkySite Platforms as needed to fill potential developing coverage gaps or adjust the altitude of individual SkySites [sic] Platforms to a new altitude with preferential winds in order to keep the constellation uniformly spaced.

SD_191247–57 at -48 (emphasis added).

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373. The Frische article also provides details of Space Data's testing of its wind steering technology, explaining: "Winds from 72k to 90k feet were below 20 miles per hour. . . . SkySite Platform float altitudes ranged from 70 thousand to 90 thousand feet during the trials as these winds provided a wide range of wind directions with minimal changes in altitude, as seen in Figure 14. By controlling the SkySite Platform altitude between 74k and 83k feet, all wind directions were available." SD_191247-57 at -54. The referenced Figure 14 is a graph of the wind conditions Space Data encountered at various altitudes during these test flights.

SD_191247-57 at -54.

374. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

375. [REDACTED]

[REDACTED]

[REDACTED]

376. Also, as noted, Space Data has allowed journalists to record and broadcast video from its NOCC, and it has provided those journalists with information concerning Space Data's

[REDACTED]." For

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example, the WSJ.com story about Space Data shows a wall monitor in Space Data's NOCC with the location and vector of Space Data's balloons in flight:



While the monitor is displayed, the narrator of the WSJ.com story explains:

While they're airborne, the balloons are monitored at Space Data's command and control center where they're projected on a big map. The blue thumbnails mark the balloons, with the circles around them representing their wireless coverage area. White vectors show where the balloons will end up in eight hours as they drift across the stratosphere. Engineers are able to adjust the balloon's altitude and keep them in place.

GOOG-SD-00292607.

377. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

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Statement	Percentage (%)
1	100
2	100
3	100
4	100
5	100
6	100
7	100
8	100
9	100
10	~85

379. Additionally, Dr. Meyer's statements concerning the benefits to Google of Space Data's Asserted Technical Trade Secrets fail to take into account the fundamental differences between Space Data's balloon communication system and the system subsequently developed by Loon.

380. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

381. Loon, in contrast, utilizes ultra-long duration super-pressure balloons that can stay aloft for months. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] Loon payloads look nothing like the Space Data payloads depicted in the Google photographs and in the public news broadcasts; they are much larger, heavier, and more complex; they are not encased in a Styrofoam; and they include solar panels for generating power while in flight.

382. Given the very different configurations and design characteristics of Space Data's system and Loon's, and the very different operational approaches of the two systems, in my opinion, knowledge of Space Data's Asserted Technical Trade Secrets, individually or collectively, would be of little value or utility to establish the viability of a system such as Loon's.

X. CONCLUSION

383. Based on my knowledge, experience, education and professional judgment, my understanding of the legal standards in this case, and my review of the evidence, it is my opinion (1) that Google has not infringed any asserted claim of the '193 and '706 patents, (2) that there are multiple acceptable non-infringing alternatives to the asserted claims of the '193 patent, and (3) that Dr. Meyer's assumptions, understandings and statements about Google's alleged

Exhibit 2

ROBERT JOHN HANSMAN JR.

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Education

MASSACHUSETTS INSTITUTE OF TECHNOLOGY - Cambridge, MA
- Ph.D. in Physics, June 1982.
Thesis under Professor Walter Hollister, "The Interaction of Radio Frequency Electromagnetic Waves with Atmospheric Water Droplets and Applications to Aircraft Ice Prevention."
- M.S. in Physics, May 1980.
Thesis under Professor George Bekefi, "Reflexing in a Relativistic e-Beam Diode."

CORNELL UNIVERSITY - Ithaca, NY
- A.B. Magna Cum Laude in Physics & Distinction in all Subjects, June 1976.

Member

National Academy of Engineering (NAE), FAA Research and Development Advisory Committee (Chair), NRC Aeronautics & Space Engineering Board, American Institute of Aeronautics & Astronautics (Fellow), Royal Aeronautical Society (Fellow), NASA Aeronautics Advisory Council, Soaring Society of America (Director), Soaring Safety Foundation (Director), Atmospheric Environment Technical Committee, American Meteorological Society, Society of Automotive Engineers, Human Factors Society, Aeronautical Flight Measurements and Techniques Working Group, Editorial Board *Air Traffic Control Quarterly* and *Journal of Aircraft*, Phi Beta Kappa, Sigma Xi.

Experience

MIT DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS - Cambridge, MA
1982 - present

Faculty member in the fields of Flight Safety, Flight Information Systems, Instrumentation, Aviation Meteorology, Human Factors, Air Transportation

Head of Systems Sector; Director of the International Center for Air Transportation.

2006 T. Wilson Professor of Aeronautics and Astronautics

1995 Professor.

1987 Associate Professor.

1985 Esther and Harold E. Edgerton Assistant Professor.

1984 Boeing Assistant Professor of Aeronautics and Astronautics.
1983 Assistant Professor.
1982 Lecturer.

PRIVATE CONSULTANT - Cambridge, MA
1982 - present
Consultant for numerous firms on aerospace related topics.

MIT FLIGHT TRANSPORTATION LABORATORY - Cambridge, MA
1980 - 1982
Graduate Research Assistant working on the physics of advanced aircraft ice prevention concepts.

MIT RESEARCH LABORATORY OF ELECTRONICS - Cambridge, MA
1976 - 1980
Graduate Research Assistant working on high power relativistic electron beam magnetrons and high current density diodes.

FRANCIS & JACKSON ASSOCIATES - Marion, MA
1976 - 1977
Consultant working on total-energy wind shear detection and autothrottle control.

CORNELL UNIVERSITY DEPARTMENT OF PHYSICS - Ithaca, NY
1975 - 1976
Recitation Instructor involved in teaching basic courses in Mechanics and Modern Physics (Optics and Quantum Mechanics).

SCHWEIZER AIRCRAFT CORPORATION - Elmira, NY (also Sugarbush, VT, Franconia, NH, North Conway, NH, and Plymouth, MA)
Summers 1971-1977
Glider and airplane flight instructor, glider and banner tow pilot, ferry pilot and test pilot for several companies.

FLIGHT EXPERIENCE - 6000+ hours: Commercial, Multi-Engine, Glider Airplane, Helicopter, Instrument, Remote Pilot and Flight Instructor Ratings. Type rated in Lear Jet 24, 35 and 55 series. Graduate of the Union Alpen Seeflugschule (Neideroblar, Austria). Extensive mountain and instrument flight experience. Engineering, Production, and Meteorological Flight Test Experience.

Awards

2015 Best Article in Journal of Cognitive Engineering and Decision Making
2013 Elected to the National Academy of Engineering
2012 CNA Award for Operational Analysis
2012 Kevin Corker Award for the Best Paper at 10th USA/Europe ATM, R&D Seminar
2007 Plenary Lecture at American Control Conference
2006 T. Wilson Chair of Aeronautics & Astronautics
2005 Best Paper in 6th USA/Europe ATM, R&D Seminar
2005 AIAA Dryden Lecture in Aviation Research
2005 Kriske Career Award from Air Traffic Control Association
2004 Laurel from Aviation Week and Space Technology
2002 Fellow of the American Institute of Aeronautics & Astronautics.
2001 NASA Turning Goals into Reality Award
1998 Bose Award for Excellence in Teaching
1998 FAA/Eurocontrol Best Paper in Air Traffic Management
1997 FAA Excellence in Aviation Award.
1994 AIAA Losey Atmospheric Sciences Award.
1990 OSTIV Diploma for Technical Contribution.
Federation Aeronautique Internationale Gold C Award with 3 Diamonds.
1986 Presidential Young Investigator Award.
1985 Esther & Harold E. Edgerton Professorship.
1984 Boeing Professorship in Aeronautics & Astronautics.
1986 AIAA Award for the Best Paper in Thermophysics.
1989 Soaring Society of America, Exceptional Service Award.
1980 and 1990 Region 1 Soaring Champion.
1984 NASA Astronaut Selection Finalist.

Patents

Microwave Ice Prevention System, U.S. Patent #4365131 issued December 21, 1982.

Method and Apparatus for Measurement of Ice Thickness Employing Ultrasonic Pulse-Echo Technique, U.S. Patent #4628736 issued December 16, 1986.

Method and Apparatus for Monitoring Liquid Volume/Mass in Tanks, U.S. Patent #4729245 issued March 8, 1988.

Optically Indicating Surface De-Icing Fluids, U.S. Patent #5039439 issued August 13, 1991.

Method and Apparatus for Detection of Ice Accretion - Remote IR Techniques, U.S. Patent #5313202 issued May 17, 1994.

Integrated Flight Information and Control System, U.S. Patent #6,389,333, issued May 14, 2002.

System and Method for Measuring the Workload of a Driver. U.S. Patent #7428449, issued September 23, 2008.

Video Production

“MIT Video Series on Measurement” (author, co-producer, and presenter), 1995:

- “Introduction to Measurement”
- “Calibration, Accuracy and Error”
- “Measuring Dynamic Variables”
- “Contact Temperature Measurement”
- “Infrared Temperature Measurement”
- “Distance, Velocity and Acceleration”
- “Mass, Force, Strain, Torque, and Pressure”
- “Measurement”
- “Fluid Quantity and Flow”

Congressional Testimony

“The Dynamics of the Emerging Capacity Crisis in the U.S. Air Traffic Control System” House Appropriations Committee –Subcommittee on Transportation, 3/15/01.

“Developing the Next Generation Air Traffic Management System” House Science Committee – Subcommittee on Space and Aeronautics”, 7/19/01.

“A Review of Aeronautics R&D at FAA and NASA” House Science Committee – Subcommittee on Space and Aeronautics”, 3/6/03.

“The Future of Aeronautics at NASA” House Science Committee – Subcommittee on Space and Aeronautics”, 3/16/05.

“Financing the Next Generation Air Transportation System” House Transportation and Infrastructure Committee – Aviation Subcommittee, 9/27/05.

“The Federal Aviation Administration’s Research and Development Capability” House Science Committee – Subcommittee on Space and Aeronautics”, 3/22/07.

“A Review of the Federal Aviation Administration’s Research and Development Program” House Science Committee – Subcommittee on Space and Aeronautics”, 2/16/11.

“Unmanned Aircraft Systems (UAS) Research and Development” House Committee on Science, Space and Technology”, 1/21/15.

“Transforming America’s Air Travel” House Committee on Science, Space and Technology”, 6/11/15.

Books

(with Belobaba, P., Barnhart, C., Odoni, A, Hansman, R.J., Swelbar, W, Waitz, I, Reynolds, T, Midkiff, A, Marias, K., Barnett, A., Kochan, T., Hoffer-Gittel, J, Merkersi, R.) , “The Global Airline Industry” (Wiley Publishing and AIAA). (updated and second printing 2014).

“Characteristics of Instrumentation,” Chapter 1, pp. 3-10 in The Measurement, Instrumentation and Sensors Handbook, Webster, J., Editor, CRC Press LLC, Boca Raton, FL, January 1999 (reprinted and updated 2013).

(with Feron, E. (Editor), Balakrishnan, H., Clarke, J.P., and, Jimenez, H.), “Challenges in Aerospace Decision and Control: Air Transportation Systems” pp. 109-136 in Advances in Control System Technology for Aerospace Operations Springer Link, SBN: 978-3-662-47693-2 (Print) 978-3-662-47694-9 (Online)

Journal Articles

“Droplet Size Distribution Effects on Aircraft Ice Accretion,” *Journal of Aircraft*, Vol. 22, No. 6, June 1985.

(with M. Kirby), “Measurement of Ice Accretion Using Ultrasonic Pulse-Echo Techniques,” *Journal of Aircraft*, Vol. 22, No. 6, June 1985.

“Measurement of Individual Hydrometeor Absorption Cross Sections Utilizing Microwave Cavity Perturbation Techniques,” *Journal of Atmospheric and Oceanic Technology*, Vol. 1, No. 4, December 1984.

“Droplet Size Distribution Effects on Aircraft Ice Accretion,” *Journal of Aircraft*, Vol. 22, No. 6, June 1985.

(with M. Kirby), “Measurement of Ice Accretion Using Ultrasonic Pulse-Echo Techniques,” *Journal of Aircraft*, Vol. 22, No. 6, June 1985.

“Performance Degradation of Natural Laminar Flow Airfoils Due to Contamination by Rain or Insects,” *Technical Soaring*, Vol. 9, No. 3, September 1985.

(with M. Barsotti), “Surface Wetting Effects on a Laminar Airfoil in Simulated Heavy Rain,” *Journal of Aircraft*, Vol. 22, No. 12, December 1985.

(with M. Kirby), “Measurement of Ice Growth During Simulated and Natural Icing Conditions Using Ultrasonic Pulse-Echo Techniques,” *Journal of Aircraft*, Vol. 23, No. 6, June 1986.

“Microwave Absorption Measurements of Melting Spherical and Non-Spherical Hydrometeors,” Journal of the Atmospheric Sciences, Vol. 43, 1643-1649, August 1986.

Journal Articles (cont.)

(with M. Kirby), "Comparison of Wet and Dry Growth in Artificial and Flight Icing Conditions," *Journal of Thermophysics and Heat Transfer*, Vol. 1, No. 3, 215-221, July 1987.

(with A. Craig), "Low Reynolds Number Tests of NACA 64-210, NACA 0012, and Wortmann FX67-K170 Airfoils in Rain," *Journal of Aircraft*, Vol. 24, No. 8, 559-566, August 1987.

(with M. Kirby, R. McKnight, and R. Humes), "In-Flight Measurement of Airfoil Icing Using an Array of Ultrasonic Transducers," *Journal of Aircraft*, Vol. 25, No. 6, June 1988.

(with L. Peterson and E. Crawley), "Nonlinear Fluid Slosh Coupled to the Dynamics of a Spacecraft," *AIAA Journal*, Vol. 27, No. 9, September 1989.

(with S. Turnock), "Investigation of Surface Water Behavior During Glaze Ice Accretion," *Journal of Aircraft*, Vol. 26, No. 2, February 1989.

(with J. Sturdy), "Dynamic Response of Aircraft-Autopilot Systems to Atmospheric Disturbances," *Journal of Aircraft*, Vol. 26, No. 2, February 1989.

(with E. Crawley), "Improving the Crashworthiness of Your Sailplane," *Soaring*, June 1989.

(with K. Kampf and E. Crawley), "Experimental Investigations of the Crashworthiness of Scaled Composite Sailplane Fuselages," *Journal of Aircraft*, Vol. 26, No. 7, July 1989.

"Measuring Airframe Ice Ultrasonically," *Avionics*, September 1989.

(with K. Yamaguchi, B. Berkowitz, and M. Potapczuk), "Modeling Surface Roughness Effects On Glaze Ice Accretion," *Journal of Thermophysics and Heat Transfer*, Vol. 5, No. 1, January 1991.

(with V. Lupi), "Development and Testing of the MIT Acoustic Levitation Testing Facilities," *Journal of Atmospheric and Oceanic Technology*, Vol. 8, No. 4, 541-552, August 1991.

(with M. Adams), "Last Hurdle for Autonomous Air Vehicles," *Aerospace America*, October 1991.

(with D. Ávila de Melo), "Analysis of Aircraft Performance During Lateral Maneuvering for Microburst Avoidance," *Journal of Aircraft*, Vol. 28, No. 12, 837-843, December 1991.

(with K. Yamaguchi), "Heat Transfer on Accreting Ice Surfaces," *Journal of Aircraft*, Vol. 29, No. 1, 108-113, January 1992.

Journal Articles (cont.)

(with C. Wanke), “Hazard Evaluation and Operational Cockpit Display of Hazardous Windshear Information,” *Journal of Aircraft*, Vol. 29, No. 3, 319-325, May 1992.

(with J. Kuchar), “An Exploratory Study of Plan View Terrain Displays for Air Carrier Operations,” *The International Journal of Aviation Psychology*, Vol. 3, No. 1, 34-54, March 1993.

(with A. Midkiff), “Identification of Important ‘Party Line’ Information Elements and Implications for Situational Awareness in the Datalink Environment,” *Air Traffic Control Quarterly*, Vol. 1 (1), 5-30, 1993.

(with E. Hahn), “Experimental Studies on the Effect of Automation on Pilot Situational Awareness in the Datalink ATC Environment,” *1992 SAE Transactions Journal of Aerospace*, Vol. 101, Sec. 1, 922292, 1957-1968, 1993.

(with E. Greitzer, E. Crawley, S. Widnall, S. Hall, H. McManus, J. Shea, and M. Landahl), “Reform of the Aeronautics and Astronautics Curriculum at MIT,” *Journal of Engineering Education*, Vol. 83, No. 1, 47-56, January 1994.

(with M. Mykityshyn, and J. Kuchar), “Experimental Study of Advanced Electronic Cockpit Displays for Instrument Approach Information,” *The International Journal of Aviation Psychology*, Vol. 4, No. 2, 141-166, July 1994.

(with R. Henry and K. Breuer), “Measurement of Heat Transfer Variation on Surface Roughness Elements Using Infrared Techniques,” *Journal of Thermophysics and Heat Transfer*, Vol. 9, No. 1, 175-180, January 1995.

(with R. Henry), “Mesure des Variations du Coefficient de Transfert sur Rugosités de Surface par Thermographie Infrarouge,” *Revue Scientifique et Technique de la Défense*, 1995 No. 4, 71-78, October 1995.

(with A. Pritchett), “Variations Among Pilots from Different Flight Operations in Party Line Information Requirements for Situation Awareness,” *Air Traffic Control Quarterly*, Vol. 4 (1), 29-50, January 1997.

(with R. Kornfeld and J. Deyst), “Single-Antenna GPS-Based Aircraft Attitude Determination,” *Navigation : Journal of the Institute of Navigation*, Vol. 45 (1), 51-60, Spring 1998.

(with H. Idris, I. Anagnostakis, B. Delcaire, J.-P. Clarke, E. Feron, and A. Odoni), “Observations of Departure Processes at Logan Airport to Support the Development of Departure Planning Tools,” *Air Traffic Control Quarterly*, Vol. 7, No. 4, 229-257, July 1999.

(with R. Barhydt), “Experimental Studies of Intent Information on Cockpit Traffic Displays,” *AIAA Journal of Guidance, Control, and Dynamics*, Vol. 22, No. 4, 520-527, July-August 1999.

Journal Articles (cont.)

(with M. Endsley, and T. Farley), "Shared Situation Awareness in the Flight Deck-ATC System," *IEEE AES Systems Magazine*, Vol. 14, No. 8, 25-30, August 1999.

(with T. Farley, K. Amonlirdviman, and M. Endsley), "Shared Information Between Pilots and Controllers in Tactical Air Traffic Control," *AIAA Journal of Guidance, Control, and Dynamics*, **23**, No. 5, 826-836, September-October 2000.

(with L. Vigeant-Langlois), "Influence of Icing Information on Pilot Strategies for Operating in Icing Conditions," *Journal of Aircraft*, **37**, No. 6, 108-113, November-December 2000.

"Complexity in Aircraft Automation: A Precursor for Concern in Human-Automation Systems," *National Forum: The Phi Kappa Phi Journal: When Technology Fails*, **81**, No. 1, 30-32, February 2001.

(with R. Kornfeld, J. Deyst, K. Amonlirdviman, and E. Walker), "Applications of GPS Velocity Based Attitude Information," *AIAA Journal of Guidance, Control, and Dynamics*, **24**, No. 5, 998-1008, September-October 2001.

(with S. Vakil), "Approaches to Mitigating Complexity-Driven Issues in Commercial Autoflight Systems," *Reliability Engineering and System Safety*, Elsevier Science, **75** (2002), 133-145, January 2002.

(with J. Histon, G. Aigon, D. Delahaye, and S. Puechmorel), "Introducing Structural Considerations into Complexity Metrics," *Air Traffic Control Quarterly*, **10(2)** 115-130, 2002.

(with T. Downen), "Identification and Analysis of Key Barriers to the Utility of General Aviation," *Journal of Aircraft*, 232-238, March-April 2003.

(with T. Reynolds), "Investigating Conformance Monitoring Issues in Air Traffic Control Using Fault Detection Techniques," *Journal of Aircraft*, 42, No.5, 1307-1317, 2005.

(with A. Mozdzanowska), "Growth and Operating Patterns of Regional Jets in the United States," *Journal of Aircraft*, **42**, No.4, 00.1307-1317, 2005

(with D. Delahaye, S. Puechmorel and J. Histon), "Air Traffic Complexity Map based on Non Linear Dynamical Systems," *Air Traffic Control Quarterly*, **12**, No. 4, 367-388, 2004.

(with Laura Major-Forest), "The Future Oceanic ATC Environment: Analysis of Mixed Communication, Navigation, and Surveillance Equipage" *Air Traffic Control Quarterly*, **12**, No.4 (2006).

Journal Articles (cont.)

(with Christopher Magee, Richard de Neufville, Renee Robins Daniel Roos), "Research agenda for an integrated approach to infrastructure planning, design and management", *Int. J. Critical Infrastructures*, Volume 2, pp. 146 – 159, Number 2-3, 2006.

(with Hayley Davison Reynolds, Tom Reynolds), "Human Factors Implications of Continuous Descent Approach Procedures for Noise Abatement in Air Traffic Control", *Air Traffic Control Quarterly*, **14(1)**, pp. 25-45, 2006.

(with Philippe Bonnefoy) "Investigation of the Potential Impact of the Entry of Very Lights in the National Airspace System", *Journal of Aircraft*, **44**, No 4, pp. 1318-1326, July-August 2007.

(with Aleksandra L. Mozdzanowska and Roland E. Weibel) "Feedback Model of Air Transportation System Change: Implementation Challenges for Aviation Information Systems", *IEEE Journal*, **96**, Issue 12, pp. 1976-1991, 2009.

(with Philippe Bonnefoy and Richard de Neufville) "Effective Development of Multi-Airport Systems; A Worldwide Perspective", *Journal of Transportation Engineering*, **136**, Issue 11 2010.

(with Sgouris Sgourdis and Philippe Bonnefoy) "Air Transportation in a Carbon Constrained World: Long-term Dynamics of Policies and Strategies for Mitigating the Carbon Footprint of Commercial Aviation", *Transportation Research - Part A Policy and Practice*, **45**, Issue 10, 2011.

(with Morrison, J. and Sgourdis, S.) "Game Theory Analysis of the Impact of Single Isle Aircraft Competition on Fleet Emissions", *Journal of Aircraft*, **49**, No.2 pp. 483-494, March-April 2012.

(with Churchill, A, Ball, M. and Donaldson, A.) "Integrating Best-Equipped Best-Served Principles in Ground Delay Programs," *Air Traffic Control Quarterly*, **20**, No 1, 2012.

(with Simaiakis, I, Khadilkar, H., Balakrishnan, H., Reynolds, T. G., Reilly, B., and Urlass, S.) "Demonstration of Reduced Airport Congestion through Pushback Rate Control", *Transportation Research Part A: Policy and Practice* (in review).

(with Marias, K., Reynolds, T., Uday, P, Muller, D, Lovegren, J. and Dumont, J.) Evaluation of Potential Near Term Operational Changes to Mitigate Environmental Impacts of Aviation" *Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering*, DOI: 10.177/0954419112454095, 1-23, July 2012.

(with Morrison,J. and Yutko, B.) "Transitioning the U.S Air Transportation System to Higher Fuel Costs" *Transportation Research Record: Journal of the Transportation Research Board*, **2266**, July 2012.

(with Palacios, R.) "Short-Term Consequences of Radio Communications Blackout on the U.S. National Airspace System" *Aerospace Sciences and Technology*, August 2013, **29** Issue 1 pp. 426-433.

Journal Articles (cont.)

(with Sandberg, M., Simaiakis, I., Balakrishnan, H. and Reynolds, T. G.) "A Decision Support Tool for Pushback Rate Control of Airport Departures" *IEEE Transactions on Systems, Man and Cybernetics Part C* (2014).

(with Palacios, R.) " Filtering Enhanced Traffic Management System (ETMS) Altitude Data" *Metrology and Measurement Systems* **20**, no. 3, <http://dx.doi.org/10.2478/mms-2013-0039>.

(with Lim, D., Kirby, M., Nam, T, Burdette, G., Yutko, B., Mozdzanowska, A., and Bonnefoy, P.) "Assessment of Carbon Dioxide Emission Metric Systems for an Aircraft Certification Standard". *Journal of Aircraft*, (2014). doi: 10.2514/1.C032279

(with Simaiakis, I., Khadilkar, H., Balakrishnan, H. and Reynolds, T) Demonstration of reduced airport congestion through pushback rate control" *Transportation Research Part A: Policy and Practice* [09658564] **66**. (2014): 251-267., <http://dx.doi.org/10.1016/j.tra.2014.05.014>

(with Silva, S., and Jensen, L.) "Safety Benefit of ADS-B Traffic and Weather Uplink Services", *Journal of Aerospace Information*, Vol. 12, No. 8, pp. 579-586, doi:[10.2514/1.I010364](https://doi.org/10.2514/1.I010364)

(with Li, L., Das, S., Palacios, R., and Srivastava, A.) "Analysis of Flight Data Using Clustering Techniques for Detecting Abnormal Operations", *Journal of Aerospace Information*, Vol. 12, No. 9 (2015), pp. 587-598. <http://dx.doi.org/10.2514/1.I010329>.

(with Silva, S.) . "Divergence Between Flight Crew Mental Model and Aircraft System State in Auto-Throttle Mode Confusion Accident and Incident Cases" *Journal of Cognitive Engineering and Decision Making* [15553434] . (2015).

(with Li, L., Palacios, R., and Welch, R.) "Anomaly Detection via a Gaussian Mixture Model for Flight Operation and Safety Monitoring", *Transportation Research, Part C*, [64](#), March 2016, pp. 45–57, [doi:10.1016/j.trc.2016.01.007](https://doi.org/10.1016/j.trc.2016.01.007).

(with Li, L., Das, S., Srivastava, A.) "Analysis of Flight Data Using Clustering Techniques for Detecting Abnormal Operations", [Journal of Aerospace Information Systems](#) 12(9):1-12 · September 2015.

Additional Publications

(with A. Palevesky and G. Bekefi), "Frequency Characteristics of the Relativistic Electron Beam Magnetron," Bulletin of the American Physical Society, April 1977.

(with R. Shefer and G. Bekefi), "Self-Pinching in a Laser Irradiated Relativistic e-Beam Diode," Bulletin of the American Physical Society, April 1978.

(with G. Bekefi), "The Reflex Diode Under Short Pulse Conditions," Proceedings of the IEEE International Conference on Plasma Physics, June 1979.

"Microwave Ice Prevention," Proceedings of the Joint University Program for Air Transportation Research, NASA Conference Publication 2224, 1981.

"The Interaction of Radio Frequency Electromagnetic Fields with Atmospheric Water Droplets and Applications to Aircraft Ice Prevention," MIT Flight Transportation Laboratory Report R82-5, 1982.

"The Effect of the Atmospheric Droplet Size Distribution on Aircraft Ice Accretion," AIAA-84-0108, AIAA 22nd Aerospace Sciences Meeting, January 1984.

"Studies of the Insect Collection Efficiency of Airfoils," Proceedings of the 4th International Symposium on the Science and Technology of Low Speed and Motorless Flight," February 1984.

(editor) "Proceedings of the 4th International Symposium on the Science and Technology of Low Speed and Motorless Flight," Soaring Society of America, February 1984.

(with R. Ausrotas), "Aviation Safety Analysis," MIT Flight Transportation Laboratory Report R84-1, April 1984.

(with M. Kirby), "Measurement of Ice Accretion Using Ultrasonic Pulse-Echo Techniques," AIAA-85-0471, AIAA 23rd Aerospace Sciences Meeting, January 1985.

(with M. Barsotti), "The Aerodynamic Effect of Surface Wetting Characteristics on a Laminar Flow Airfoil in Simulated Heavy Rain," AIAA-85-0260, AIAA 23rd Aerospace Sciences Meeting, January 1985.

(with M. Kirby), "Measurement of Ice Accretion Using Ultrasonic Pulse Echo Techniques," Proceedings of the Joint University Program for Air Transportation Research - 1984, NASA CP-2452, January 1985.

"Performance Degradation of Natural Laminar Flow Airfoils Due to Contamination by Rain or Insects," Proceedings of the Soaring Society of America Meeting, March 1985.

Additional Publications (cont.)

“Low Gravity Fluid Measurement & Fluid Structure Interactions,” Proceedings of the In-Space Research, Technology & Engineering Workshop, October 1985.

(with M. Kirby), “Experimental Methodologies to Support Aircraft Icing Analysis,” Proceedings of the Joint University Program for Air Transportation Research - 1985, NASA CP-2453, January 1986.

(with M. Kirby), “Real-Time Measurement of Ice Growth During Simulated and Natural Icing Conditions Using Ultrasonic Pulse-Echo Techniques,” AIAA-86-0410, AIAA 24th Aerospace Sciences Meeting, January 1986.

(with M. Kirby), “Experimental Measurements of Heat Transfer From an Iced Surface During Artificial and Natural Cloud Icing Conditions,” AIAA-86-1352, AIAA/ASME 4th Joint Thermophysics and Heat Transfer Conference, June 1986, (selected as the Best AIAA Paper in Thermophysics for 1986).

(with L. Peterson and E. Crawley), “Nonlinear Coupled Dynamics of Fluids and Spacecraft in Low Gravity,” Tenth U.S. Congress of Applied Mechanics, June 1986.

(with L. Peterson and E. Crawley), “The Coupled Dynamics of Fluids and Spacecraft in Low Gravity and Low Gravity Fluid Measurement,” Proceedings of the NASA/OAST Microgravity Fluid Management Symposium, September 1986.

(with L. Peterson and E. Crawley), “Experimental Measurements of the Nonlinear Coupled Dynamics of Fluids and Spacecraft in Low Gravity,” Proceedings of the 37th Congress of the International Astronomical Federation, Innsbruk, October 1986.

(with M. Kirby), “Ultrasonic Ice Measurement Techniques for Aircraft Applications,” Proceedings of the 2nd International Symposium on Aviation Safety, Toulouse, November 1986.

(with A. Craig), “Comparative Low Reynolds Number Tests of NACA 64-210, NACA 0012, and Wortmann FX67-K170 Airfoils in Heavy Rain,” AIAA-87-0259, AIAA 25th Aerospace Sciences Meeting, January 1987.

(with M. Kirby, R. McNight, and R. Humes), “In-Flight Measurement of Ice Growth on an Airfoil Using an Array of Ultrasonic Transducers,” AIAA-87-0178, AIAA 25th Aerospace Sciences Meeting, January 1987.

(with J. Sturdy), “Assigned Altitude Deviation Caused by Dynamic Response of Aircraft-Autopilot Systems to Atmospheric Perturbations,” ICAO# RGCSP-WG/B-WP/40, ICAO Review of the General Concept of Separation Panel, Montreal, January 1987.

Additional Publications (cont.)

(with S. Turnock), "Investigation of Surface Water Behavior During Glaze Ice Accretion," AIAA-88-0015, AIAA 26th Aerospace Sciences Meeting, January 1988.

(with J. Sturdy), "Dynamic Response of Aircraft-Autopilot Systems to Atmospheric Disturbances," AIAA-88-0578, AIAA-88-0692, AIAA 26th Aerospace Sciences Meeting, January 1988.

(with L. Peterson and E. Crawley), "The Nonlinear Dynamics of a Spacecraft Coupled to the Vibration of a Contained Fluid," AIAA-88-2470, AIAA /ASME/ASCE/AHS 29th Structures Dynamics & Materials Conference, April 1988.

(with M. Kirby), "An Experimental and Theoretical Study of the Ice Accretion Process During Artificial and Natural Icing Conditions," Joint NASA/FAA Contractor Report, NASA CR-182119, DOT/FAA/CT-87/17, April 1988.

(with J. Meserole), "Fundamental Limitations on Low Gravity Fluid Gauging Technologies Imposed by Orbital Mission Requirements," AIAA-88-3402, AIAA/ASME/SAE/ASEE 24th Joint Propulsion Conference, July 1988.

(with S. Turnock), "Investigation of Microphysical Factors which Influence Surface Roughness During Glaze Ice Accretion," Paper A5-2, Proceedings of the Fourth International Workshop on Atmospheric Icing of Structures, Paris, September 1988.

(with F. Lichtenfelsz and M. Kirby), "Ultrasonic Techniques for Aircraft Ice Accretion Measurement," AIAA-88-4656-CP, AIAA/NASA/AFWAL Conference on Sensors and Measurement, September 1988.

(with B. Kang), "Preliminary Definition of Pressure Sensing Requirements for Hypersonic Vehicles," AIAA-88-4652-CP, AIAA/NASA/AFWAL Conference on Sensors and Measurement, September 1988.

"Ice Detection Technology," SAE Aircraft Ground Deicing Conference Proceedings, P-217, September 1988.

"The Influence of Ice Accretion Physics on the Forecasting of Aircraft Icing Conditions," AMS/WMO Third International Conference on the Aviation Weather System, Paper 5.1, January 1989.

(with J. Riley, M. Potapczuk, B. Berkowitz and K. Yamaguchi), "Modeling Surface Roughness Effects on Glaze Ice Accretion," AIAA-89-0734, AIAA 27th Aerospace Sciences Meeting, January 1989.

Additional Publications (cont.)

(with C. Wanke), "Cockpit Display of Hazardous Weather Information," AIAA-89-0808, AIAA 27th Aerospace Sciences Meeting, January 1989.

(with D. Chandra and S. Bussolari), "A Comparison of Communication Modes for Delivery of Air Traffic Control Clearance Amendments in Transport Category Aircraft," Fifth International Symposium on Aviation Psychology, April 1989.

(with V. Lupi), "Preliminary Results From the MIT Acoustic Levitation Test Facility," Midwest Association for Cloud and Aerosol Physics, May 1989.

(with D. Ávila de Melo), "Analysis of Aircraft Performance During Lateral Maneuvering for Microburst Avoidance," AIAA-90-0568, AIAA 28th Aerospace Sciences Meeting, January 1990.

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(with K. Yamaguchi), "Heat Transfer on Accreting Ice Surfaces," AIAA-90-0200, AIAA 28th Aerospace Sciences Meeting, January 1990.

(with A. Dershowitz), "Passive Infrared Ice Detection for Helicopter Applications," AHS 46th Annual Forum, May 1990.

(with V. Lupi), "Development and Testing of the MIT Acoustic Levitation Test Facility," American Meteorological Society Conference on Cloud Physics, July 1990.

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PROOF OF SERVICE

I am employed in the City and County of San Francisco, State of California in the office of a member of the bar of this court at whose direction the following service was made. I am over the age of eighteen years and not a party to the within action. My business address is Keker, Van Nest & Peters LLP, 633 Battery Street, San Francisco, CA 94111-1809.

On November 16, 2018, I served the following document(s):

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Executed on November 16, 2018, at San Francisco, California.

I declare under penalty of perjury under the laws of the State of California that the above is true and correct.

Len P
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